POLYCHLORINATED BIPHENYLS (PCB'S) DISPOSAL AND TREATMENT TECHNOLOGIES - AN UPDATE

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Polychlorinated biphenyls (PCB's) are one of the most misunderstood and feared classes of chemicals known, especially to the general public. They have been singled out in the Legislatures and news media of this country as posing a general threat to human health. Certain environmentalists, legislators and the media have dubbed PCB's as "deadly toxins", "human and animal cancer-causing agents" and "life threatening chemicals." This has resulted in a public perception that the slightest presence of PCB's represents a significant hazard to health and the environment.

PCB's are the only chemical substance which Congress singled out and targeted for immediate regulatory action by the EPA Administrator under the Toxic Substances Control Act - TSCA (40 CFR 761). Under TSCA, regulations banning U.S. manufacture and new uses were promulgated as well as regulations controlling remaining uses, storage and ultimate disposal.

Politics, the media and bureaucratic prejudices have resulted in an exaggerated and unreasonable fear of PCB's. Public concern has made it very difficult to develop and gain

approval of suitable technologies and commercial facilities for the safe disposal and destruction of PCB's.

It is in this context that I would like to review briefly the status of current PCB disposal rules and existing technologies with emphasis on those commercially practices. In addition, I want to discuss and update emerging technologies for commercial disposal of PCB's which are visible in the future.

Currently, PCB disposal (including storage and all other facets) is totally regulated by TSCA. For disposal purposes, PCB's can be broken down into three basic categories (Section 761.10).

I. PCB Liquids -- Any liquid stream containing PCB's at a concentration of 500 ppm or higher, including pure PCB's (100%).

II. PCB Contaminated Liquids -- Any liquid stream containing PCB's at a concentration in the range of 50 ppm to 499 ppm. Includes contaminated mineral oils.

III. PCB Solids (Non-Liquids) -- Contaminated equipment, including transformers, capacitors, machinery, containers, debris and dirt from spills and clean-ups, dredge spoils, sludges.

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TSCA regulations also specify basic technologies (Section 761.10) and their criteria (Section 761.40, 761.41) for actual disposal of PCB's and related items.

A.	Incinerator	Annex I CFR 761.40
B.	Chemical Waste Landfill	Annex II CFR 761.41
C.	High-Efficiency Boiler	CFR 761.10(a) (2) (IV) and (3) (IV)
D.	Alternate Disposal Method	Approved by Regional Administrator; achieves performance level equivalent to Annex I incinerators or high-efficiency boilers. CFR 761.10(e)

A summary of PCB disposal options for various types of wastes and technologies is summarized in Table 1.

Specific examples of industrial PCB wastes, along with currently employed disposal methods, is illustrated in Table 2.

In many cases, more than one PCB disposal technology is permitted and feasible for a given waste. In these instances the disposal method chosen will depend on factors other than technology, such as direct costs; proximity to a commercially available (and approved) disposal facility; minimization of handling, storage and exposure; societal factors, e.g., neighbors, workers and media attitudes, etc.

I'd like to briefly discuss the status of each of these currently available PCB disposal options, including the location of EPA approved facilities for each one.

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TABLE 1

SUMMARY OF PCB DISPOSAL OPTIONS FOR VARIOUS WASTES AND TECHNOLOGIES

	PCB LIQUIDS	PCB CONTAMINATED LIQUIDS	PCB SOLID MATERIALS
	≥500 ppm	50 - 449 ppm	
Incineration	☐+	+	+
High-Efficiency Boiler	-	☐+	-
Hazardous Waste Landfill	-	+	☐+
Potential Alternate Disposal Technology	+	+	+

+ Permitted by Regulations
- Not Permitted by Regulations
☐ Generally Used Commercially

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TABLE 2

EXAMPLES OF PCB DISPOSAL METHODS FOR VARIOUS INDUSTRIAL PCB WASTES

TYPE OF WASTE	DISPOSAL METHOD	WASTE SOURCE
PCB Solid Materials	Incineration (Annex I)	Capacitors* Sludges Dredge Spoils Spill Debris/clothing, building materials, paper, sorbents
	Landfill (Annex II)	Containers* Drained Transformers*, Machinery* Sludges* Dredge Spoils* Spill Debris* Contaminated Soil*
PCB Liquids (≥ 500 ppm PCB)	Incineration (Annex I)	Transformer Fluids* 50-100% PCB Hydraulic Fluids* Heat Transfer Fluids* Chemical Mfg. Still Residues*

*Generally employed commercially for these wastes

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TABLE 2 (Continued)

EXAMPLES OF PCB DISPOSAL METHODS FOR VARIOUS INDUSTRIAL PCB WASTES

TYPE OF WASTE	DISPOSAL METHOD	WASTE SOURCE
PCB Contaminated Liquids (50 - 499 ppm)	Incineration (Annex I)	Transformer Mineral Oil Contaminated Oils and Solvents
	High Efficiency Boilers	Transformer Mineral Oil* Contaminated Oils and Solvents* Non-aqueous Fluids*
	Landfill (If not "ignitable") (Annex II)	Dilute aqueous streams,* washings, rinses, etc. Dilute non-ignitable organic streams, rinses

*Generally employed commercially for these wastes

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Incineration thus far is the method most used worldwide for PCB disposal.

Safe and acceptable disposal of PCB wastes by high-temperature incineration has been known and practiced by the scientific and industrial world since PCB's were first discovered to be environmentally persistent in the late 1960's. Methods and criteria written into TSCA regulations (Annex I) were practiced on an industrial scale many years prior to the regulations themselves.

High-temperature incineration is a proven method of hazardous waste destruction used to routinely handle both solid and liquid forms of all kinds of chemical wastes, including PCB's and other chlorinated compounds. Many commercial chemical waste incinerators are currently in use in the U.S.

In Europe, many hazardous waste disposal facilities include high-temperature incineration equipment to routinely handle a variety of chemical wastes -- both solid and liquid, including PCB's and other halogenated hydrocarbons. These wastes include sludges, contaminated earth and other debris as well as liquids. At least a dozen such facilities are currently in operation there and have been functioning satisfactorily for several years. Many of the European facilities are currently owned and operated by both the

government and private sectors. All of these recognized facilities are capable of destroying PCB's in an environmentally acceptable manner with no human health hazard.

In both the U.S. and Canada, successful test burns of PCB's in various high-temperature incinerators have been accomplished while under scrutiny by appropriate State and Federal regulatory agencies. This includes the Rollins Environmental Services facility at Deer Park, Texas, and ENSCO at El Dorado, Arkansas. Both of these commercial facilities meet the rigid specifications, including destruction efficiencies, prescribed by Federal regulations under the Toxic Substances Control Act (40 CFR 761), Annex I, and have been approved by the EPA for incineration of PCB's.

Based upon the results of these tests, EPA scientists and officials and other interested parties have concluded that these two U.S. incinerators are capable of destroying PCB's without harming human health or the environment.

Recently, the ocean incinerator ship *VULCANUS*, operated by Waste Management, Inc., underwent test burns of PCB materials in the Gulf of Mexico. Analysis of results of those tests are not complete at this time.

Currently, only two commercial incinerators have been approved in the U.S. for PCB disposal, even though almost five years have elapsed since the passage of TSCA. This is a

result of over-reaction -- over-regulation, indecision and politics in government and citizens' opposition caused by fear generated in part by the media -- all due to a lack of understanding of the technical basis for assessing degree of hazard and risk associated with PCB use and exposure.

Cement kilns have also been successfully evaluated for disposal of PCB's by incineration. Results of tests at three plants in Canada, the United States and Sweden demonstrated that cement kilns do provide a safe and viable means of PCB incineration. However, in the U.S. (Peerless Cement Co., Detroit, Michigan) and Canada (St. Lawrence Cement, Mississauga, Ontario) citizens' opposition, despite credible scientific evidence of the success of the test, forced authorities to not grant authorization and permits for use of cement kilns for PCB's destruction. This is illustrative of the point made earlier concerning the need for a less emotional and more factual public awareness so that suitable and safe disposal sites can be located where they are needed without confronting misguided fear and opposition. Many citizen activists groups share this concern and have now begun working to assure that suitable disposal facilities are available.

High-efficiency boilers represent another method permitted under TSCA for destruction of contaminated PCB fluids in the 50-499 ppm PCB range. This technology offers the opportunity

to efficiently dispose of large volumes of contaminated liquids such as transformer mineral oils and flushing materials used to decontaminate hydraulic and heat transfer systems. The prime use for such disposal systems would be electric utilities or industries having large quantities of electrical transformers and/or PCB contaminated fluids periodically requiring the disposal.

The exact number of high-efficiency boilers permitted to burn PCB contaminated oils and fluids in the U.S. is not generally, known, but is very low. Most utilities as well as other industries are faced with the immediate storage of PCB contaminated waste for future disposal.

Some of the known industries permitted to dispose of PCB's in their high-efficiency boilers are listed in Table 3.

Landfill or burial of certain PCB wastes, particularly solid materials, is permitted under TSCA regulations. This includes drained equipment such as transformers and containers and debris, sludges, etc., as shown previously in Table 2. This presentation will not discuss landfill technology for PCB's; however, I will briefly review the current list of EPA Hazardous Waste Landfills approved for disposal of certain PCB wastes. These are shown in Table 4.

Currently, only eight facilities in the U.S. have EPA approval for landfill disposal of PCB wastes.

The geographical distribution of the U.S. EPA approved sites for PCB disposal by incineration and landfill is illustrated on the map in Figure 1.

Continued use of the California landfill site is questionable under recent legislation in that state prohibiting burial of any PCB's.

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TABLE 3

EPA APPROVED HIGH-EFFICIENCY BOILERS FOR PCB DISPOSAL*

Public Service Company of NH	Merrimac Station, NH	Utility
Union Electric Company	St. Louis, MO	Utility
General Motors, Chevrolet Division	Bay City, MI	Manufacturing
Northeast Utilities	Middleton, CT	Utility
Baltimore Gas & Electric	Train Station Chase, MD	Utility
Tennessee Eastman Company	Kingsport, TN	Manufacturing

*Partial listing of known, approved sites

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TABLE 4

CHEMICAL WASTE LANDFILLS APPROVED FOR PCB DISPOSAL

SITE LOCATION	FACILITY	FACILITY ADDRESS	PROPERLY DRAINED TRANSFORMERS	CONTAMINATED SOIL, DIRT, RAGE & OTHER DEBRIS	DREDGE SPOILS	MUNICIPAL SLUDGES	PROPERLY DRAINED CONTAINERS	ASPHALT (CONTAMINATED)	LIQUID PCBs AT A CONCENTRATION BETWEEN 50 & 500 ppm
ALABAMA	WASTE MGMT. OF ALABAMA (205) 652-9531 TOLL FREE NO. (800) 241-7820	P.O. BOX 1200 LIVINGSTON AL 35470	X	X	X	X	X		X
CALIFORNIA	CASMALIA DISPOSAL (805) 969-0997	530 YSIDRO ROAD P.O. BOX 6275 SANTA BARBARA CA. 93108	X	X	X	X	X		
GRAND VIEW, IDAHO	WES-CON, INC. (208) 834-2275	P.O. BOX 664 TWIN FALLS ID 83301	X	X			X	X	X
BEATTY, NV	NUCLEAR ENGINEERING CO., INC. (502) 426-7160	9200 SHELBYVILLE RD. SUITE 528 P.O. BOX 7246 LOUISVILLE KY 40207	X	X	X	X	X		
NEW YORK	CECOS INTERNATIONAL (716) 731-3281	4520 ROYAL AVE. NIAGARA FALLS NY 14303	X	X	X	X	X		
NEW YORK	SCA CHEMICAL SERV., INC. (716) 754-8231	1650 BALMER ROAD MODEL CITY NY 14107	X	X	X	X	X		
OHIO	CECOS INTERNATIONAL (513) 724-6114	5002 ABER RD. WILLIAMSBURG OH 45176	X	X	X	X	X		X
OREGON	CHEM-NUCLEAR SYS. INC. (800) 223-1012	P.O. BOX 1200 PORTLAND OR 97205	X	X			X	X	X

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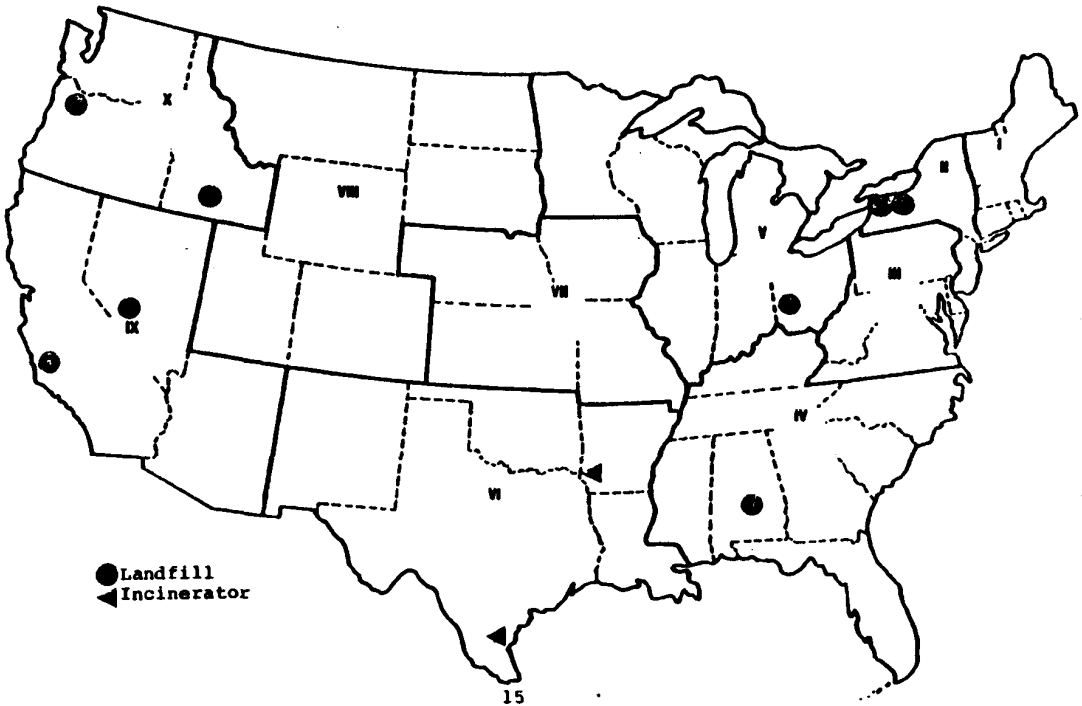
Figure 1

GEOGRAPHICAL DISTRIBUTION OF U.S. EPA APPROVED COMMERCIAL PCB DISPOSAL SITES



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Finally, I'd like to review the status of various potential alternate disposal technologies that have emerged recently. As we noted earlier (in Table 1), even though the EPA defined strict criteria and methodology for PCB disposal initially, the drafters of the regulations had enough foresight to allow for technological advancement affording new techniques to help solve the PCB disposal problem (CFR 761.10(e)).

Regardless of the disposal methodology considered, there are several areas of concern that always arise when discussing PCB disposal. These are: (1) siting, (2) dispersion of trace quantities of PCB's and other trace pollutants (especially from combustion technologies), (3) side reactions (potential formation of other, more hazardous compounds) and (4) actual destruction products. Emerging technologies generally attempt to significantly relieve one or more of these areas of concern.

In all probability, there will be no one technological panacea capable of handling and disposing of all forms of PCB contaminants to the satisfaction of all parties. However, emerging technologies will be capable of addressing specific needs and applications and many of these are now in the development, approval and commercialization stages.

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Most of the emerging alternate PCB disposal methods can be classified either as thermal or chemical destruction techniques.

Thermal techniques, including classical incineration, encompass a variety of methods and equipment ranging from flame combustion or pyrolysis, to exotic techniques such as plasma arcs and microwave destruction.

Table 5 presents a listing of thermal destruction techniques/ equipment for PCB disposal, including current timetables to commercialization.

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TABLE 5

THERMAL TECHNIQUES/EQUIPMENT FOR PCB DISPOSAL

METHOD	EQUIPMENT	APPLICABLE WASTE TYPE	STATUS/EXAMPLES	% PCB DESTRUCTION EFFICIENCY REPORTED	REMARKS
Incineration (Annex I) (PCB Levels >500 ppm)	Liquid Injection[a]	Liquid PCB Streams	Commercial/Rollins Envir. Services - Texas	99.99999	Temp. 1200° - 1600°C
			Under Test/Ocean Ship *VULCANUS*	---	
	Rotary Kiln[a]	Solids, Liquids & Equipment	Commercial/ENSCO - Arkansas	99.99998	
	Cement Kiln	Liquid Streams (Fuel Supplement)	Test Approval/Peerless Cement Co. - Michigan	99.99998	Project abandoned due to citizen opposition
High-Efficiency Boilers (PCB Levels 50-499 ppm)	Industrial Steam Boilers[a]	Liquid, Contaminated Oils, Solvents, etc.	Approved In Use/Union Electric Co. - Missouri	>99.9	Fixed installation, use generally limited to users' own wastes. (Several others approved/ in use.)
			Approved In Use/General Motors - Michigan	>99.9997	
			Approved In Use/Florida Light & Power Co. - Florida		
Fluidized Bed Incinerator	Special Design	Liquid Streams, Shredded Paper, Finely Divided Materials, Viscous Streams	Test Demonstration Completed/ Rockwell Internat'l, Environ. & Energy Systems, Rocky Flats, Colorado	>99.9999	Available for license temp. <695°C, chromic oxide catalyst
Molten Salt Incinerator	Special Design	Liquid Streams, Shredded Paper, Solids, e.g., Metal Resins, Dirt, Debris, etc., Viscous Streams	Test Demonstration Applied For/Rockwell Internat'l, Environ. & Energy Systems, Canoga Park, California	>99.9992	Available for license temp. 750°-900°C, potential portable systems, cost is approx. $2M unit

[a]Current commercial usage

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TABLE 5 (Continued)

METHOD	EQUIPMENT	APPLICABLE WASTE TYPE	STATUS/EXAMPLES	% PCB DESTRUCTION EFFICIENCY REPORTED	REMARKS
Plasma Arc	Torch - Special Design - Electrically Generated "Plasma" Arc	All Types of Wastes: Liquid, Shredded Solids, Small Parts, etc.	In R&D Stages/Royal Military College of Canada, Kingston, Ontario. Trial Burn Early 1982	Very high expected	Extremely high, localized temp. up to 50,000°F, portable unit applicable to all forms of waste
	MHD (Magneto Hydro-Dynamics power generation)	Liquid Streams	In R&D Stages/Pyro-Magnetics Corp. - Whitman, MA and U of TN Space Inst. - Tullahoma, Tennessee. Trial Burn Requested	Expected "six nines"	Temp. to 50000°F, uses supplemental O_2
Microwave	Undisclosed	Undisclosed	R&D Stage/Lockheed Research Center - Palo Alto, California	—	Described as "incineration"
Diesel Engine	Special Design Diesel Engine	Liquid Streams, Mixed Waste, Diesel Fuel	R&D Stages/D&D Disposal Ltd. - Smithville, Ontario, Canada, Under Further Testing	99.998	Temp. approx. 590°C, initial engine cost approx. $250-$300M
Pyrolysis	—	All Types	R&D Stage		Few details available

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In summary, several new thermal/incineration methods look very encouraging. Of particular interest are those technologies possessing portability. All other factors being equal, portability could overcome citizen concerns with siting of major permanent facilities and could minimize transportation, handling, etc. However, cost-effectiveness and competitiveness with other disposal technologies cannot be determined at this time.

Although thermal/incineration methods have as yet been the major technology employed in PCB disposal, a number of significant new chemical destruction methods are beginning to emerge which offer promise of some specialized applications at least.

Most of the chemical destruction methods involve liquid phase processes. (This is in distinction to incineration and other thermal processes which for the most part are gas-phase systems.)

Basically, the chemical destruction processes can be categorized as two types:

1. Processes which destroy the biphenyl structure (such as previous incineration/combustion processes)
2. Processes which dechlorinate the organic biphenyl molecule and thus "detoxify", as opposed to destruction

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Accordingly, the operating conditions, such as temperature, pressure, residence time, etc., and equipment requirements will vary with the reaction type.

There are several liquid-phase dechlorination processes which are currently in various stages of research, development, approval-testing and commercialization. These innovative processes are listed in Table 6. Also shown in this table for completeness is electron beam irradiation, a dechlorination process which has undergone some exploratory research.

The dechlorination processes are characterized generally by the following traits:

1. Use of sodium or similar reagent to strip chlorine from an organic molecule.

2. Operate in liquid phase at mild temperature and pressure.

3. Portable, complete disposal units. Equipment can be used on-site.

4. Used for clearly defined, non-aqueous waste streams having low PCB levels, usually less than 1,000-5,000 ppm; e.g., transformer oil, hydraulic fluid flushings.

5. Treated fluids capable of resource recovery/reuse.

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6. Cost per gallon of fluid is moderate (e.g., $3-$5/gallon).

7. Have obtained EPA approval in many Regions and are in use commercially.

Several chemical destruction processes under development are listed in Table 7. These have met with only limited technical success in most cases and, to my knowledge, none have been approved by EPA as alternate PCB disposal methods nor are they expected to be commercially available in the near future.

For completeness, Table 8 lists one last PCB disposal methodology which is best categorized as physical separation methods. At least three of the four known process methods are employed commercially. These can best be viewed as volume reduction processes rather than destruction/detoxification processes. The end result is that the "concentrated" PCB wastes must be disposed of by conventional EPA approved methods.

TABLE 6

CHEMICAL METHODS FOR PCB DISPOSAL - DECHLORINATION

COMMON NAME/COMPANY	REAGENT SYSTEM	STATUS
Goodyear Process	Sodium, naphthalene, tetrahydrofuran	Patent dedicated to public. Entrepreneurs may develop commercial processes.
PCBX - SunOhio	Proprietary - believed to be sodium type	Portable. Approved EPA Region I, III, IV, IX, X; pending Region VI, XIII.
Accurex	Sodium-type system	EPA demonstration/pending
NaPEG/General Electric	Sodium/polyethylene glycol	Pilot plant developed. Test demonstration requested.
NaPEG/Franklin Institute	Sodium/polyethylene glycol	Tests in progress on contaminated soils in Rhode Island and Wisconsin.
PPM Inc.	Undisclosed - believed to be sodium type	Test completed. Final review process Region VII.
Electron Beam Irradiation	Low energy electrons. Commercially available sources, e.g., Radiation Dynamics	Used on trace levels. Work performed at MIT. Preliminary research.

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TABLE 7

CHEMICAL METHODS FOR PCB DISPOSAL - DESTRUCTION

COMMON NAME/COMPANY	REAGENT SYSTEM	STATUS
Wet Oxidation	Zimpro-type processes. Research demonstrated on other organochlorine wastes, e.g., Pentachlorophenol.	Requires high temperature, pressure, long residence times.
Super oxide oxidation (negatively charged ozone)	U of Calif.-Riverside (does not require ozone); Zone-Oxide® gas oxidations - R&D stages. Demonstration applied for (requires ozone); oxyphotolysis process, Houston Research.	Very preliminary stages
UV Radiation/Oxidation	Research stage at USDA Lab	Uses soil microorganisms
Microorganisms ("Super Bugs", Genetic Engineering Bacteria)	Dr. Chakrobarty, U of Illinois Dr. Pierce, Battelle Labs	Applied to 2,4,5-T herbicide and 2,4-D and other organochlorine compounds.

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TABLE 8

PHYSICAL SEPARATION METHODS FOR PCB DISPOSAL

COMMON NAME	REAGENT SYSTEM/COMPANY	REMARKS
Super Critical Fluid Extraction	Super critical CO_2 used to extract organics, e.g., caffeine/coffee	Preliminary stages. Arthur D. Little, Inc., investigators.
Carbon Absorbtion*		
Organic Matrix Absorbtion, e.g, Neoprene Rubber*	EPAC® commercial systems sold as filter unit	In use.
Capacitor Resource Recovery*	SED, Inc. - Wisconsin EII - Kansas City, Missouri	Physical removal of capacitor components; destroy PCB's; recover oils, metals, etc. Approved by EPA.

*Used Commercially

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In Conclusion --

I'd like to point out that this is a dynamic area.... innovation can be both frequent and rapid. But most of the emerging technologies appear to be geared for specialized applications involving rather dilute PCB systems. For the foreseeable future, incineration, high-efficiency boilers and approved landfills will continue to be the primary methods of disposal and destruction.

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